SBML Model Report

Model name: “Gardner2000 - genetic toggle switch in E.coli”

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1 General Overview

This is a document in SBML Level 3 Version 1 format. This model was created by the following two authors: Vijayalakshmi Chelliah[1] and Nicolas Le Novre[2] at January 19th 2014 at 7:51 p. m. and last time modified at November 26th 2014 at 11:26 a. m. Table 1 shows an overview of the quantities of all components of this model.

Table 1: Number of components in this model, which are described in the following sections.

Element	Quantity	Element	Quantity
compartment types	0	compartments	1
species types	0	species	3
events	0	constraints	0
reactions	4	function definitions	2
global parameters	9	unit definitions	5
rules	1	initial assignments	2

Model Notes

Gardner2000 - genetic toggle switch in E.coli

The behaviour of the genetic toggle switch and the conditions for bistability has been studies using a synthetic, bistable gene circuit.

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This model is described in the article:Construction of a genetic toggle switch in Escherichia coli.Gardner TS, Cantor CR, Collins JJNature. 2000 Jan 20;403(6767):339-42.

Abstract:

It has been proposed' that gene-regulatory circuits with virtually any desired property can be constructed from networks of simple regulatory elements. These properties, which include multistability and oscillations, have been found in specialized gene circuits such as the bacteriophage lambda switch and the Cyanobacteria circadian oscillator. However, these behaviours have not been demonstrated in networks of non-specialized regulatory components. Here we present the construction of a genetic toggle switch-a synthetic, bistable gene-regulatory network-in Escherichia coli and provide a simple theory that predicts the conditions necessary for bistability. The toggle is constructed from any two repressible promoters arranged in a mutually inhibitory network. It is flipped between stable states using transient chemical or thermal induction and exhibits a nearly ideal switching threshold. As a practical device, the toggle switch forms a synthetic, addressable cellular memory unit and has implications for biotechnology, biocomputing and gene therapy.

This model is hosted on BioModels Database and identifiedby: BIOMD0000000507 .

To cite BioModels Database, please use: BioModels Database: An enhanced, curated and annotated resourcefor published quantitative kinetic models .

2 Unit Definitions

This is an overview of five unit definitions.

2.1 Unit `length`

Name length

Definition m

2.2 Unit `area`

Name area

Definition m^2

2.3 Unit `volume`

Name volume

Definition l

2.4 Unit time

Name time

Definition s

2.5 Unit substance

Name substance

Definition mol

3 Compartment

This model contains one compartment.

Table 2: Properties of all compartments.

Id	Name	SBO	Spatial Dimensions	Size	Unit	Constant	Outside
compartment_1	compartment	0000290	3	1		☑	

3.1 Compartment compartment_1

This is a three dimensional compartment with a constant size of one litre.

Name compartment

SBO:0000290 physical compartment

4 Species

This model contains three species. Section 10 provides further details and the derived rates of change of each species.

Table 3: Properties of each species.

Id	Name	Compartment	Derived Unit	Constant	Boundary Condition
species_1	U	compartment_1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
species_2	V	compartment_1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟
species_3	IPTG	compartment_1	$\mathrm{mol} \cdot \mathrm{l}^{-1}$	⊟	⊟

5 Parameters

This model contains nine global parameters.

Table 4: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
parameter_1	alpha1		156.250		☑
parameter_2	alpha2		15.600		☑
parameter_3	beta		2.500		☑
parameter_4	gamma		1.000		☑
parameter_5	K		$2.9618 \cdot 10^{-5}$		☑
parameter_6	nu		2.002		☑
parameter_7	Umodif		0.000		⊟
ModelValue_4	Initial for K		$2.9618 \cdot 10^{-5}$		☑
ModelValue_5	Initial for nu		2.002		☑

6 Initialassignments

This is an overview of two initialassignments.

6.1 Initialassignment ModelValue_4

Derived unit contains undeclared units

Math parameter_5

6.2 Initialassignment ModelValue_5

Derived unit contains undeclared units

Math parameter_6

7 Function definitions

This is an overview of two function definitions.

7.1 Function definition function_1

Name toggle repressor production

SBO:0000393 production

Arguments alpha, X, n

Mathematical Expression

$$\frac{\text{alpha}}{1 + \text{X}^{\text{n}}} \tag{1}$$

7.2 Function definition `function_2`

Name toggle repressor production with induction

SBO:0000393 production

Arguments alpha, X, n

Mathematical Expression

$$\frac{\text{alpha}}{1 + \text{X}^{\text{n}}} \tag{2}$$

8 Rule

This is an overview of one rule.

8.1 Rule `parameter_7`

Rule `parameter_7` is an assignment rule for parameter `parameter_7`:

$$\text{parameter\_7} = \frac{[\text{species\_1}]}{\left(1 + \frac{[\text{species\_3}]}{\text{ModelValue\_4}}\right)^{\text{ModelValue\_5}}} \tag{3}$$

9 Reactions

This model contains four reactions. All reactions are listed in the following table and are subsequently described in detail. If a reaction is affected by a modifier, the identifier of this species is written above the reaction arrow.

Table 5: Overview of all reactions

№	Id	Name	Reaction Equation	SBO
1	`reaction_1`	production of U	$\emptyset \xrightarrow{\text{species\_2, species\_2}} \text{species\_1}$	0000393
2	`reaction_2`	degradation of U	$\text{species\_1} \xrightarrow{\text{species\_1}} \emptyset$	0000179
3	`reaction_3`	production of V	$\emptyset \longrightarrow \text{species\_2}$	0000393
4	`reaction_4`	degration of V	$\text{species\_2} \xrightarrow{\text{species\_2}} \emptyset$	0000179

9.1 Reaction reaction_1

This is an irreversible reaction of no reactant forming one product influenced by two modifiers.

Name production of U

SBO:0000393 production

Reaction equation

$$\emptyset \xrightarrow{\text{species\_2, species\_2}} \text{species\_1} \tag{4}$$

Modifiers

Table 6: Properties of each modifier.

Id	Name	SBO
species_2	V	
species_2	V	

Product

Table 7: Properties of each product.

Id	Name	SBO
species_1	U	

Kinetic Law

Derived unit contains undeclared units

$$v_1 = \text{vol}\left(\text{compartment\_1}\right) \cdot \text{function\_1}\left(\text{parameter\_1}, [\text{species\_2}], \text{parameter\_3}\right) \tag{5}$$

$$\text{function\_1}\left(\text{alpha}, \text{X}, \text{n}\right) = \frac{\text{alpha}}{1 + \text{X}^{\text{n}}} \tag{6}$$

$$\text{function\_1}\left(\text{alpha}, \text{X}, \text{n}\right) = \frac{\text{alpha}}{1 + \text{X}^{\text{n}}} \tag{7}$$

9.2 Reaction reaction_2

This is an irreversible reaction of one reactant forming no product influenced by one modifier.

Name degradation of U

SBO:0000179 degradation

Reaction equation

$$\text{species\_1} \xrightarrow{\text{species\_1}} \emptyset \tag{8}$$

Reactant

Table 8: Properties of each reactant.

Id	Name	SBO
species_1	U	

Modifier

Table 9: Properties of each modifier.

Id	Name	SBO
species_1	U	

Kinetic Law

Derived unit mol

$$v_2 = \text{vol}\,(\text{compartment\_1}) \cdot \text{k1} \cdot [\text{species\_1}] \tag{9}$$

9.3 Reaction reaction_3

This is an irreversible reaction of no reactant forming one product.

Name production of V

SBO:0000393 production

Reaction equation

$$\emptyset \longrightarrow \text{species\_2} \tag{10}$$

Product

Table 10: Properties of each product.

Id	Name	SBO
species_2	V	

Kinetic Law

Derived unit contains undeclared units

$$v_3 = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \mathrm{function\_2}\left(\mathrm{parameter\_2}, \mathrm{parameter\_7}, \mathrm{parameter\_4}\right) \tag{11}$$

$$\mathrm{function\_2}\left(\mathrm{alpha}, \mathrm{X}, \mathrm{n}\right) = \frac{\mathrm{alpha}}{1 + \mathrm{X}^{\mathrm{n}}} \tag{12}$$

$$\mathrm{function\_2}\left(\mathrm{alpha}, \mathrm{X}, \mathrm{n}\right) = \frac{\mathrm{alpha}}{1 + \mathrm{X}^{\mathrm{n}}} \tag{13}$$

9.4 Reaction `reaction_4`

This is an irreversible reaction of one reactant forming no product influenced by one modifier.

Name degration of V

SBO:0000179 degradation

Reaction equation

$$\mathrm{species\_2} \xrightarrow{\mathrm{species\_2}} \emptyset \tag{14}$$

Reactant

Table 11: Properties of each reactant.

Id	Name	SBO
`species_2`	V	

Modifier

Table 12: Properties of each modifier.

Id	Name	SBO
`species_2`	V	

Kinetic Law

Derived unit mol

$$v_4 = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \mathrm{k1} \cdot \left[\mathrm{species\_2}\right] \tag{15}$$

10 Derived Rate Equations

When interpreted as an ordinary differential equation framework, this model implies the following set of equations for the rates of change of each species.

Identifiers for kinetic laws highlighted in gray cannot be verified to evaluate to units of SBML `substance` per `time`. As a result, some SBML interpreters may not be able to verify the consistency of the units on quantities in the model. Please check if

- parameters without an unit definition are involved or
- volume correction is necessary because the `hasOnlySubstanceUnits` flag may be set to `false` and `spacialDimensions`> 0 for certain species.

10.1 Species species_1

Name U

Notes concentration of repressor 1

Initial concentration $0\ \mathrm{mol} \cdot \mathrm{l}^{-1}$

This species takes part in three reactions (as a reactant in reaction_2 and as a product in reaction_1 and as a modifier in reaction_2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{species\_1} = v_1 - v_2 \tag{16}$$

10.2 Species species_2

Name V

Notes concentration of repressor 2

Initial concentration $0\ \mathrm{mol} \cdot \mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in reaction_4 and as a product in reaction_3 and as a modifier in reaction_1, reaction_1, reaction_4).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{species\_2} = v_3 - v_4 \tag{17}$$

10.3 Species species_3

Name IPTG

Initial concentration $0\ \mathrm{mol} \cdot \mathrm{l}^{-1}$

This species does not take part in any reactions. Its quantity does hence not change over time:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{species\_3} = 0 \tag{18}$$

A Glossary of Systems Biology Ontology Terms

SBO:0000179 degradation: Complete disappearance of a physical entity

SBO:0000290 physical compartment: Specific location of space, that can be bounded or not. A physical compartment can have 1, 2 or 3 dimensions

SBO:0000393 production: Generation of a material or conceptual entity.

SBML2LaTeX was developed by Andreas Dräger[a], Hannes Planatscher[a], Dieudonné M Wouamba[a], Adrian Schröder[a], Michael Hucka[b], Lukas Endler[c], Martin Golebiewski[d] and Andreas Zell[a]. Please see http://www.ra.cs.uni-tuebingen.de/software/SBML2LaTeX for more information.

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